Progress of the Charged Pion Semi-Inclusive Neutrino Charged-Current Cross Section in NOvA

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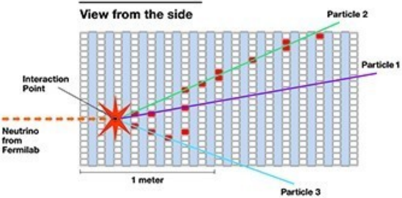
New Perspectives

Fermilab

June 5-6, 2017

- NOvA is an off-axis neutrino oscillation experiment, looking for ν_μ to ν_e oscillations.
- NOvA uses the NuMI beam and has two functionally identical detectors, with a long baseline of 810 km.

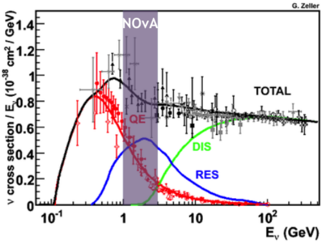


- ND placed 105 m underground, placed close to neutrino production target, has intense rate of neutrino interactions, providing a great opportunity to study neutrino-nucleus interactions.

- Charged pion production in ν_μ CC interactions.

  $$\nu_\mu + N \rightarrow \mu^{\mp} + N + \pi^{\pm} + X$$

  - a single charged pion produced could make the event mimic the CCQE topology.



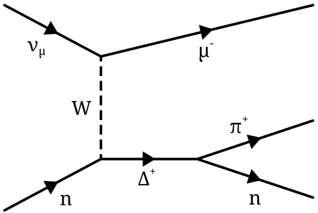


Fig. Summary of the current knowledge of ν_μ charged-current cross sections (Plot courtesy of G. Zeller) and Feynmann diagram for ν_μ CC resonant single pion production, the dominant channel for pion production.

- Aiming to measure differential cross section of ν_μ CC interactions with at-least one pion with respect to muon kinematics.

$$\frac{d\sigma_\nu}{dX_i} = \frac{\sum_j U_{ij}(N_j - N_j^{bkg})}{\varepsilon_i \Delta X_i \Phi_\nu T}$$

where i, j index of true and reconstructed bin respectively.

U_{ij} - unfolding function, calculating the contribution of reconstructed bin to true bin

ΔX_i - width of bin i, Φ_ν - integrated flux

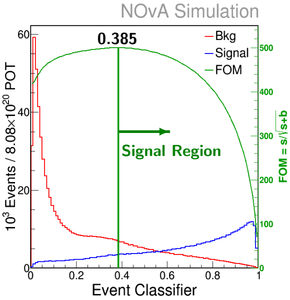
ε_i - selection efficiency

N_j and N_j^{bkg} - number of selected and background events respectively

T - number of nucleons in the fiducial volume

- Showing Monte Carlo based study
- POT exposure corresponds to 8.08e20.

- Event Selection
  - Quality (interactions triggering atleast 20 hits), containment cut and muon identification - best tracks for the muons.
  - Applied as Pre-Selections.
- Signal Selection - CVN(Convolutional Visual Network)
  - Uses full near detector raw data image as an input.
  - Trains CC events with at-least one charged pion in the final state.



Optimized on $\frac{s}{\sqrt{s+b}}$, gives maximum figure of merit at 0.385.

- A ν_μ CC interaction having one muon and at-least one charged pion in the final state.
- Events with CVN-Pi > 0.385 are selected as candidate ν_μ CC events with atleast one charged pion.

Selection Cuts	**Selected**	**Signal**	**Efficiency (%)**	**Purity (%)**	**NC (%)**	**CC 0pi (%)**	**Others (%)**
Preselections	2,693,750	1,051,800	—	39.05	1.65	56.15	3.16
CVN-Pi > 0.385	580,246	380,890	36.21	65.64	1.33	30.86	2.18

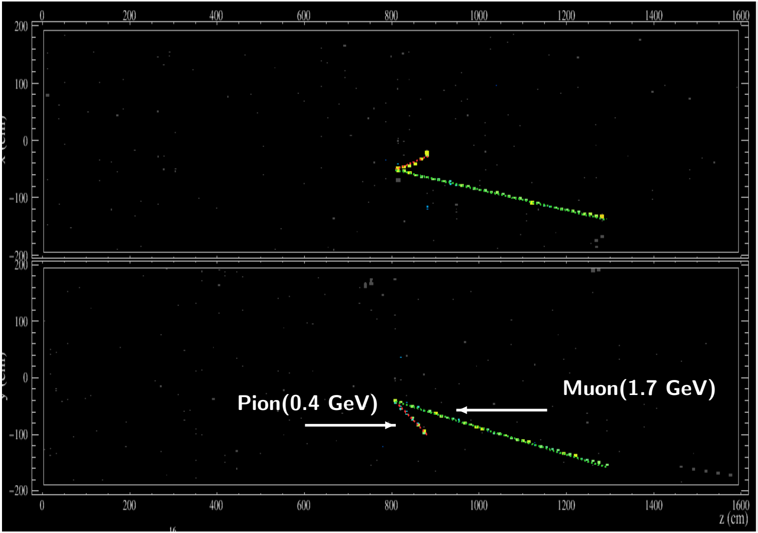
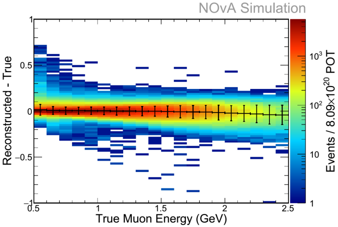
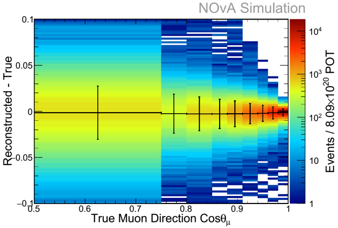


Fig. Simulation of a NOvA event



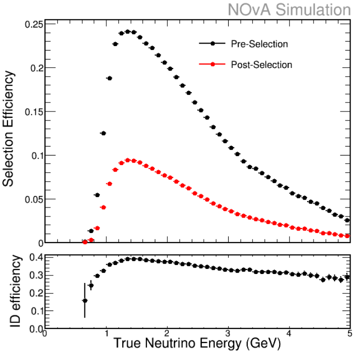


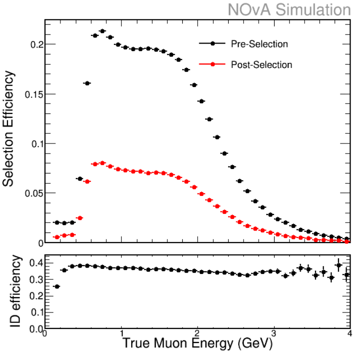
The markers show a mean fit value, and the error bands show sigma from a gaussian fit.

- The predicted resolution for both muon energy and angle are promising, provide us with an opportunity to perform differential cross section measurements.

$$\frac{d\sigma_\nu}{dX_i} = \frac{\sum_j U_{ij}(N_j - N_j^{bkg})}{\varepsilon_i \, \Delta X_i \Phi_\nu T} \qquad \varepsilon_i = \frac{N_{selected}}{N_{total}}$$

$N_{selected}$ - Number of selected signal events
N_{Total} - Total number of signal events generated



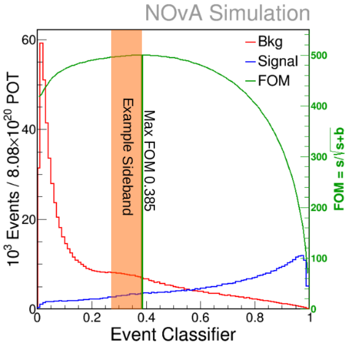


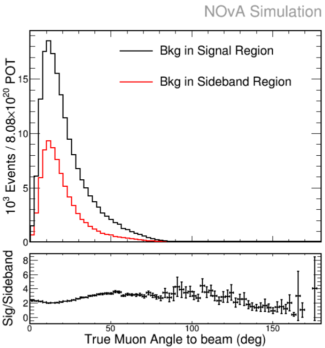
- The total efficiency of the event selection is few percent.
- PID does not restrict the available truth space.

Background Estimation

$$\frac{d\sigma_\nu}{dX_i} = \frac{\sum_j U_{ij}(N_j - N_j^{bkg})}{\varepsilon_i \Delta X_i \Phi_\nu T}$$

- Constrain background N_j using sideband region close to the signal but low predicted signal count.
- This data driven technique can produce weights by fitting the background components in the sideband.
- Can help correct the MC background events in the signal region
- Tried an example sideband region $0.275 < 0.385$





- Sideband region covers the phase space in the signal region.
- Trying with fitting of different observables.

- The study of backgrounds in the sideband region is underway.
- Looking at the possible avenues to improve the event selection efficiency.
- Start with systematics, after the sideband and efficiency studies.
- Interesting measurement, could help disentangle the nuclear effects in neutrino-nucleus interactions.